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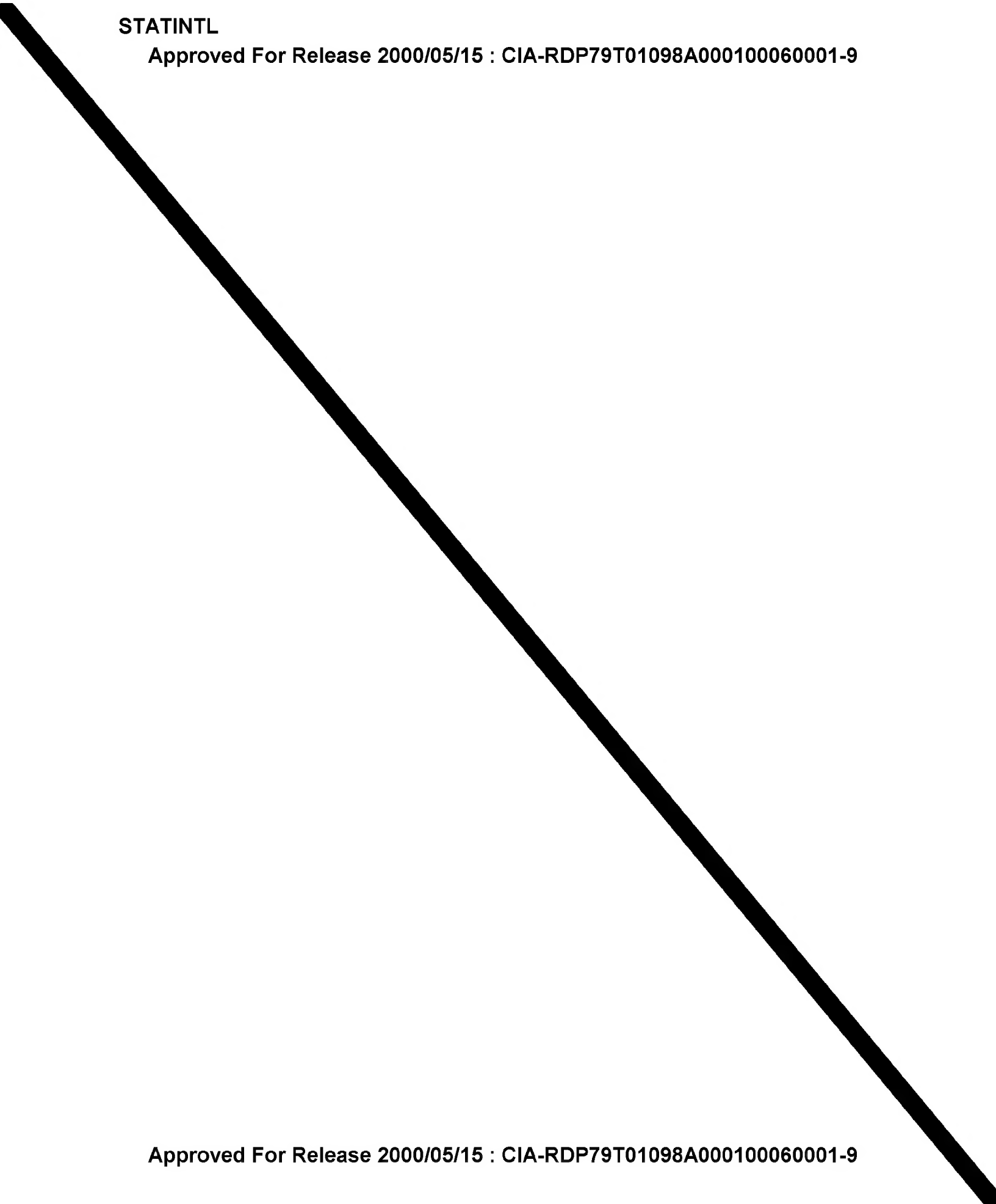

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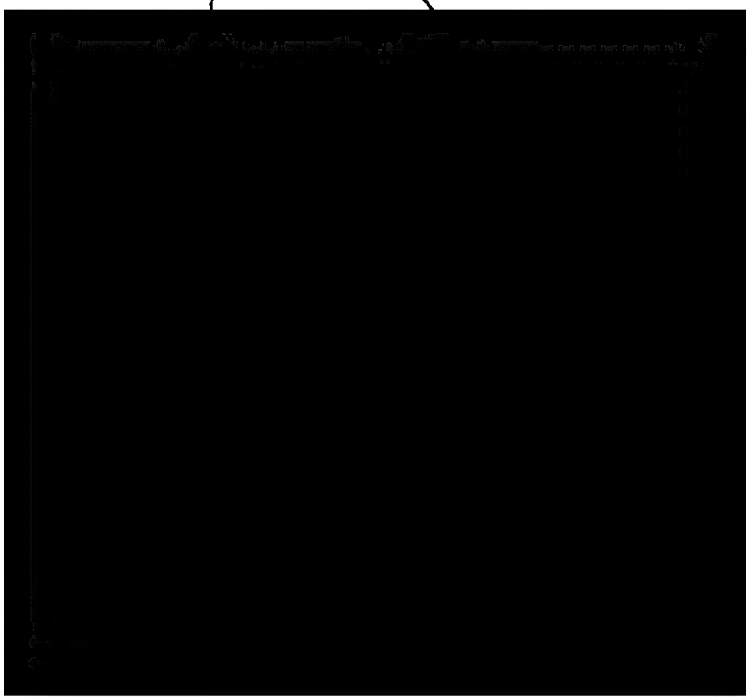

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USSR Pushes Production of Numerical Control Machine Tools

ER RP 73-6
May 1973

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Foreword

Numerical control (NC) machining technology was developed in the United States in 1952 by the Massachusetts Institute of Technology for the US Air Force. During the 1960s, NC technology developed rapidly in the United States and spread to Western Europe and Japan. The international COCOM embargo and unilateral US restrictions on exports of strategic goods effectively curtailed the export of this technology to the USSR. As of 1968 the USSR was far behind the United States, Western Europe, and Japan in the design, development, and production of NC machines. In that year, however, the USSR launched a program to accelerate the introduction and production of NC machine tools and by 1971 had become the world's largest producer, although in level of technology and quality it still lagged far behind the West.

This publication examines Soviet progress in the development and production of NC metalcutting machine tools* and Soviet efforts to accelerate

* Numerical controls are also applied to certain types of metalforming machine tools and other machinery (such as drafting machines). However, these applications are insignificant.

progress through technical cooperation agreements with firms in Western Europe and Japan. It also includes, as background, the production and use of machine tools generally in the USSR and compares Soviet machine tool production with that of the United States.

Preliminary definitions of NC technology and related considerations are discussed first (paragraphs 10-19), followed by a general discussion of the production and uses of machine tools in the USSR (paragraphs 20-37). Discussion of the Soviet NC program proper begins with paragraph 38.

USSR Pushes Production of Numerical Control Machine Tools

Summary and Conclusions

1. Numerical control (NC) machine tools represent a revolutionary innovation in metalcutting machining technology. One NC machine tool is capable of replacing two to four conventional types. Among industrialized countries, NC technology is most advanced in the United States, followed closely by Western Europe and Japan, and is least advanced in the USSR. Currently, Soviet NC technology lags 7 to 10 years behind that of the United States.

2. Despite a technology lag, and a belated start in production, the USSR now produces more NC machine tools than any other country. Output in 1972 amounted to 3,038 units, nearly double US output.

3. The USSR also is the world's largest producer of machine tools, mostly highly standardized, general-purpose metalcutting machines of the type that are easiest and least costly to produce. The USSR tends to produce general-purpose metalcutting

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Note: Comments and queries regarding this publication are welcomed. They may be directed to [redacted] of the Office of Economic Research, Code 143, Extension 6901.

machines, rather than special-purpose types, because they can be mass-produced. As a result, much of the Soviet machine tool output fails to meet the needs of users and, indeed, forces users to manufacture, at high cost, their own specialized machinery. Thus, although the USSR economizes on the production of machine tools through mass-production techniques, it loses out on the economies of specialization; hence it tends to produce cheap machine tools but expensive final products.

4. Large requirements for general-purpose machine tools are generated by Soviet efforts to modernize the entire stock of machine tools in use in production and in a large and scattered repair network. About 17% of the Soviet machine tool stock is 20 years old or older and in need of replacement. A significant percentage of machines 10 to 20 years of age also need to be replaced because, relative to new machines, productivity is low and costs of operation high. About one-third of all metalcutting machine tools in use in the USSR are used for repair and for production of spare parts.

5. The effort to modernize the stock of machine tools in both production and repair may be misdirected. The Soviets need to replace only those in production but should reorganize the repair network to reduce the need for more machines and to serve as a second-hand market for older ones now in use in production.

6. Two parallel programs for NC development and production are in being in the USSR: one in the aviation industry to service industries producing aerospace and military hardware; one in the machine tool industry to service the needs of civilian industry. In 1970, about 35% of the total output of NC machines was for aerospace and military uses. Aerospace and military production also absorbs a large proportion of the annual output of NC machine tools in the United States.

7. A major Soviet effort is under way in the current plan period to accelerate output of NC machine tools. Planned output in 1975 is to be four times that of 1970. Several firms in Western Europe and Japan have entered into cooperative NC production and marketing arrangements with the USSR. For example, Alcatel of France, Saab-Scania

of Sweden, and Siemens of West Germany are shipping NC controllers to the USSR for mating with Soviet machine tools. Some are to be sold subsequently in the respective domestic markets of the supplying countries. Fujitsu of Japan has agreed to provide NC production technology to the USSR.

8. NC machines can be helpful to the USSR in the modernization of its machine tool stock. However the impact of this technology on Soviet machinery production is likely to be less than in the United States and may fall far short even of Soviet expectations. To an important extent, the effectiveness of NC machines in the USSR will depend on whether plant management is sufficiently flexible to use them properly.

9. Furthermore, the Soviet NC machine tool program appears headed in the same direction as conventional machine tool production. Emphasis is on large-scale output of NC machines that are easiest to produce, mostly point-to-point types -- many governed by obsolescent plugboard controllers. Moreover, unlike the United States, the USSR is not designing and building NC machines as fully integrated systems. Instead, controllers are

mated to existing models of conventional machine tools that have been suitably modified to receive them. Such machine tools lack the durability, precision, and flexibility of integrated systems.

Discussion

Background

What are NC Machine Tools?

10. NC machines are machine tools such as lathes or milling, drilling, and boring machines whose movements are controlled automatically by a controller instead of by a human operator. Generally, controllers are electronic,[1] although some devices that are essentially electromechanical in operation -- so-called "plugboard" or "dial-programmed" systems[2] -- also sometimes are classified as numerical controllers. Relatively simple in design, and severely limited in capability, these systems are obsolescent in the United States, although they continue to figure prominently in the Soviet NC program.

11. Normally, a numerical controller is dedicated to the control of a single machine tool and is not a computer. However, in some advanced sys-

1. A machining program (instructions) is fed into the controller on magnetic or punched tape.
2. Machine instructions are entered by plugs and dials or by adjusting rheostats or valves.

tems of NC technology, in which simultaneous control over the operations of more than one machine tool is carried out (direct numerical control -- DNC), the controller is a computer.

12. Two types of control over the movement of the machine tool may be distinguished. First, point-to-point (or positioning) control, the most common type, is basically a point locating system used primarily with drilling or boring machines to machine a workpiece at one or more discrete points. The system is relatively uncomplicated, requires a small volume of input data, and is manufactured at relatively low cost. Second, contouring (or continuous path) control generally is used with lathes or milling machines to machine a workpiece continuously into complex shapes or contours. Contouring requires constant synchronization of the tool's motion in at least two axes. Hence, it requires a large amount of input data, high-speed control logic, and powerful servomechanisms. Contouring control of three or more axes usually requires a computer to prepare the machining program.

13. An advanced type of NC machine tool that provides for automatic changing of cutting tools,

performs multiple machining operations (for example, milling, drilling, and boring), and can be designed for either point-to-point or contouring operations is called a machining center.

14. An advanced technique for maintaining optimum metalcutting efficiency and precision by automatically adjusting the speed and feed of the cutting tool according to sensor feedback is called adaptive control. It compensates for variables that are subject to in-process change such as workpiece hardness and thickness, cutting tool wear, and rigidity of both tool and machine.

Costs and Benefits

15. Typically, in the United States, NC machine tool systems cost two to four times as much as analogous non-NC machines and range from as low as US $25,000 for simple point-to-point types to more than $500,000 for highly specialized types of contouring machining centers. In addition, NC machine tools require larger support costs -- mainly for programming and tape debugging -- and extra maintenance expenses for specialized electronic equipment and tooling. Costs or prices of NC machine tools in the USSR generally are not avail-

able. The one price that has been published -- 13,700 rubles for a contouring system -- appears to be very low and suggests that NC production in the USSR may be heavily subsidized.

16. The relatively high initial cost of NC machines in the United States is more than offset by gains in productivity, savings in labor costs, and reduction in other operational expenditures. NC machines also have unique technological advantages; they make possible the machining of intricate parts that is not feasible using conventional manually operated machine tools. In addition, they make possible greater precision (closer tolerances) and a high degree of uniformity in the precision of similar machined parts (repeatability). Generally, NC machine tools are used under conditions of low-volume production.[3]

17. Large increases in machine productivity are possible with NC technology because human interaction with the machine tool during the machining process is greatly reduced.[4] Also, manufactur-

3. For high-volume production, automated machine tools and automated transfer machinery are more efficient.

4. For example, reduction of operator fatigue and non-productive activities such as checking parts tolerances between operations, constant reviewing and checking of blueprints, and handling and resetting of workpieces.

ing leadtime and setup time are shortened because machining program tapes can be stored and quickly interchanged at the machine and because complicated templates, jigs, and fixtures are eliminated. Thus, in US experience, an NC machine tool is able to cut metal 80% (or more) of the time versus 20% for conventional machine tools; in effect, one NC machine does the work of four or more conventional ones. Furthermore, NC technology cuts costs in parts inspection, scrap and rework, and finished goods and spare parts inventory.

18. The productivity of NC machine tools, however, depends to a large extent on the quality and training of plant operating personnel and the manner and degree of integration of NC machines into the plant production process. Hence, whether the USSR can maximize productivity gains from the use of NC technology to the same extent as the United States will hinge on the flexibility of Soviet plant organization and management, as well as on the quality and capabilities of the machine tool itself.

19. Because of unique precision machining characteristics, NC machine tools continue to be

used extensively in aerospace and military industry production in the United States. Because of their extraordinary productivity and versatility relative to manually operated systems, however, they are now applied widely in civilian industrial production as well.

Significant Aspects of Soviet Machine Tool Production and Use

Production Characteristics and Comparison with the United States

20. The USSR is the world's largest producer of machine tools (see Table 1 and Figure 1). Total output in 1972 amounted to about 254,000 units, or more than two and one-half times that of the United States (95,000). Annual output of metal-cutting machine tools, in particular, is enormous. In 1972 the USSR produced about 210,000 metal-cutting machine tools, or about five times the number produced in the United States (about 42,000[5]). However, in 1972 the United States imported as many metalcutting machine tools as it produced (about 42,000 units), mostly high-quality general-

5. Excluding those valued at less than $1,000 -- mainly household types that have no direct counterparts in the USSR.

Table 1

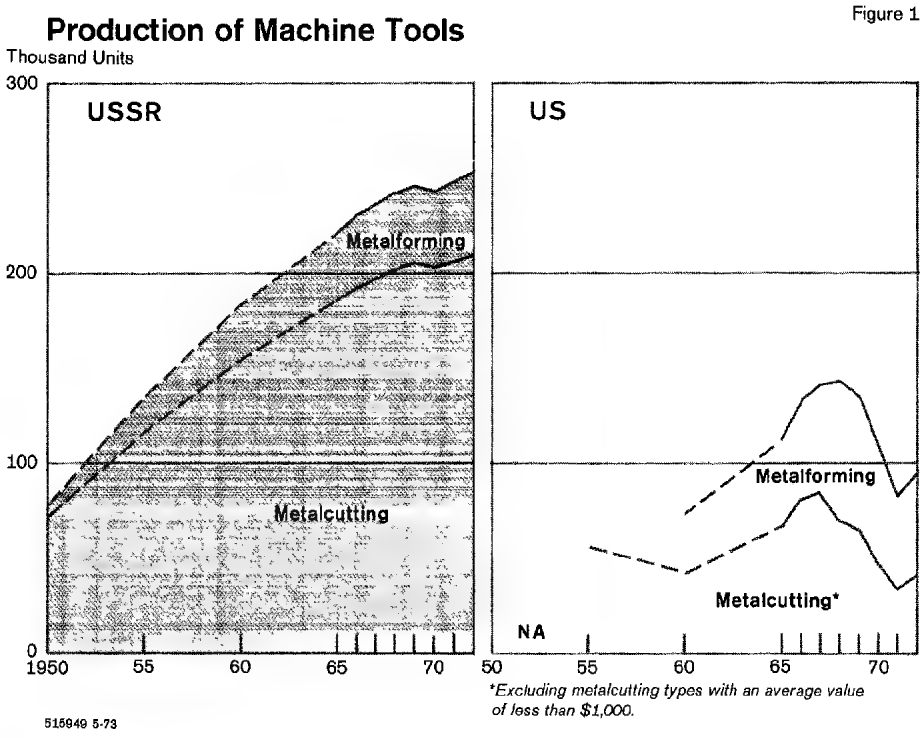
USSR and US: Production of Machine Tools

Units

	1950	1955	1960	1965	1966	1967	1968	1969	1970	1971	1972
Total											
USSR	**78,284**	**134,217**	**185,833**	**220,737**	**230,612**	**238,126**	**242,728**	**247,969**	**243,528**	**249,496**	**253,900**
US	**N.A.**	**N.A.**	**74,214**	**112,005**	**134,299**	**140,633**	**141,050**	**137,658**	**107,614**	**81,943**	**94,789**
Metalcutting											
USSR	70,600	117,100	155,900	186,100	192,200	197,000	200,600	205,300	202,260	207,200	210,000
US[1]	N.A.	58,000	42,914	68,005	80,673	86,014	70,520	65,169	49,314	32,443	41,589
Metalforming											
USSR	7,684	17,117	29,933	34,637	38,412	41,126	42,128	42,669	41,268	42,296	43,900
US	N.A.	N.A.	31,300	44,000	53,626	54,619	70,530	72,489	58,300	49,500	53,200

1. Excluding metalcutting types with an average value of less than $1,000.

Figure 1



purpose machines from Western Europe and Japan.[6] Soviet output of metalcutting machine tools was two and one-half times as large as US output plus imports.

21. At the end of 1971 the total Soviet inventory of machine tools amounted to 4.4 million units, including 3.6 million metalcutting machines. Thus the Soviet inventory of all machine tools was 52% larger than that of the United States (2.9 million), and the pool of metalcutting types was 64% larger (2.2 million). These relationships are striking because Soviet industrial output is substantially less than that of the United States.

22. The USSR also produces metalforming machine tools in large quantity -- 44,000 in 1972 compared to 53,000 in the United States -- but they account for only about 17% of total Soviet machine tool output, compared to about 56% in the United States. In many applications, metalforming machine tools are more productive, require less labor input than metalcutting types, and save on metal. For these reasons, the Soviets have planned for several years

6. Machine tools made in Western Europe and Japan compare favorable in quality and technical capabilities with those made in the United States and are cheaper.

to increase the share of metalforming machines, thus far unsuccessfully, and to expand the product mix. Most of the metalforming machine tools produced in the USSR are relatively simple types: general-purpose mechanical presses, hammers, shears, and bending machines. The USSR does not produce nearly enough high-speed hydraulic presses, precision forging machines, hot and cold stamping machines, and other modern, automated types.

23. Soviet metalcutting machine tools lack the durability, precision, and flexibility of their US counterparts. For example, Soviet machine tools require a major overhaul every 7-9 years, compared with 12-15 years in the United States. Reportedly, about one-third of the metalcutting tool stock in the USSR is under constant repair. Furthermore, users of Soviet tools complain that initial levels of accuracy of many models are quickly lost. Soviet gearcutting machines installed at the Gor'kiy Motor Vehicle Plant in 1970 lost their original levels of precision within 6 months.

24. Inferior levels of accuracy and durability are the result of poor workmanship, mismanagement at the plant level, and poor quality control and

manufacturing precedures. For example, castings frequently are not properly stress-relieved (affecting durability) and slide components are not properly hardened (affecting accuracy) owing to efforts by plant managers to cut corners in order to reduce costs, to increase plant profits, and to reach targeted output goals.

25. Two major characteristics sharply distinguish the Soviet machine tool industry from that of the United States. First, emphasis is placed on mass production. More than 60% of all metal-cutting machine tools are mass-produced. In the United States, most machine tools are produced in small lots and mass-produced machine tools are rare. Second, emphasis is also placed on output of highly standardized, general-purpose machines of relatively simple design. Basic models are kept in production, without major modification, for protracted periods -- many for 15-20 years. In 1970 the USSR produced more than 61,000 engine lathes, nearly one-third of the entire output of metalcutting machines produced in that year and ten times the number produced in the United States (see Table 2). Again, the USSR produced more than

Table 2

USSR and US: Production of Metalcutting Machine Tools in 1970 by Major Type

	Units		Percent	
	USSR	US	USSR	US
Total	**202,260**	**49,314**	**100.0**	**100.0**
Engine lathes	61,487	6,214	30.4	12.6
Automatic and semi-automatic lathes	5,663	2,416	2.8	4.9
Milling machines	21,642	11,441	10.7	23.2
Boring machines	5,056	789	2.5	1.6
Grinding machines	17,597	10,109	8.7	20.5
Drilling machines	24,271	3,255	12.0	6.6
Gearmaking machines	4,450	1,036	2.2	2.1
Other	62,094	14,054	30.7	28.5

24,000 upright, floor-type drill presses, its second largest category of output (12%), or seven and one-half times as many as in the United States. Thus, more than 40% of all metalcutting machines are simple types that are easiest and least costly to produce. By contrast, most US machine tools are specialized types that have been tailored to customer specifications and needs. Hence, in most applications, US machine tools are not only more productive but also are more expensive than Soviet machine tools.

26. By mass-producing general-purpose machine tools and neglecting special-purpose types, the USSR produces cheap machine tools but expensive

final products. Because general-purpose machines frequently are inadequate, users are forced to make expensive modifications, or to build their own specialized machinery. It is extraordinary that about one-sixth of all the metalcutting machine tools produced in the USSR -- 37,000 units in 1972, an amount nearly equal to total US production of metalcutting machine tools -- is manufactured in plants outside the Soviet machine tool industry, that is, by user plants. More than four-fifths of all the "automatic lines" produced in the USSR in 1970 were manufactured in user plants or by machine tool plants as a sideline. In fact, most of the specialized machine tools produced in the USSR probably are built by user facilities.

27. Because the USSR does not produce high-quality specialized and precision machines, particularly automated types, in sufficient quantities, it has been unable to meet the demand of large, new industrial investment projects from domestic production. Virtually all of the machine tools used to equip the new passenger car plant at Tol'yatti came from the West, and the USSR is purchasing large quantities of machine tools in the United

States, Western Europe, and Japan for its huge Kama heavy-duty truck plant under construction at Naberezhnye Chelny. Other precision, high-technology machine tools have been imported from the West during the past few years for the modernization of other plants in the automotive industry as well.

Uses

28. The USSR has a relatively greater need for metalcutting machine tools than the United States because of its overwhelming emphasis on capital goods production. In many cases, heavy machinery items can be produced only by metalcutting techniques. By contrast, the United States produces relatively greater quantities of consumer durables than the USSR -- output that is especially suited to the use of metalforming machinery. Nevertheless, a greater use of metalforming machine tools would be logical even with the Soviet product mix.

29. Second, large numbers of machine tools are needed because of the lack of vertically integrated production in the machinery industry. Reliance on sub-contracting arrangements as practiced in the United States would permit wider specialization in

the production of machinery components and reduce the overall need for machine tools.

30. Third, the USSR requires a large stock of general-purpose machine tools to supply the needs of a huge, largely unspecialized repair and spare parts industry, which is itself the result of poor quality of original equipment. Virtually every plant and farm in the USSR has a workshop set aside to repair machine tools and other machinery. In 1970, more than two and one-half million workers and more than one million metalcutting tools, or nearly one-third of the entire Soviet stock of 3.4 million metalcutting tools, were used in repair and to produce spare parts. This is a matter of grave concern to the Soviets because machine tools are used inefficiently in this application; according to official Soviet data, they are used only about 40% of the time, and then only to 15%-20% of capacity.

31. Because one-third of all metalcutting machines are used in repair work and one-third are constantly under repair, it may be inferred that nearly two out of every three machine tools in the

Soviet inventory, at any one time, are nonproductive[7] -- that is, only about one out of every three metalcutting tools is actually being used to produce machinery and other industrial goods.

32. A large quantity of machine tools also is needed annually to replace the aging and obsolescent portion of the machine tool stock. In 1970, about 17% of the metalcutting stock was 20 years of age or older and needed to be replaced, according to Soviet sources. The proportion was even higher for machine tools in use in the machinery sector. According to one Soviet study, a "significant" proportion of machine tools 10-20 years of age also should be replaced because rising maintenance costs and declining productivity, relative to new machines, no longer justifies their continuance in use.

33. In recent years, about 2%-2.5% of the stock of metalcutting machine tools has been replaced annually, representing about 35%-40% of annual output. This rate has not been sufficient

7. Based on the assumption that most of the machine tools under repair are those in use outside of the repair sector. This assumption seems reasonable since, according to the Soviet press, the machine tool stock in the repair sector is newer than that used for the production of machinery generally and, as has been pointed out, is not used very intensively.

to reduce significantly the proportion of machine tools 20 years of age or older and needing to be replaced. That proportion has declined by less than 1% per year since 1962.

34. According to Soviet data, a 6%-8% replacement rate is needed to modernize the stock of metalcutting machine tools. Such a rate is unattainable in practice because it would require virtually the entire annual output of metalcutting machine tools and leave only token quantities available for installation in new plants and for export.[8]

35. In the United States, the inventory of machine tools is older than in the USSR -- the average age is more than 20 years -- but it is more modern. It is older because about 30% of the machine tools in use at the end of World War II are still in operation; fully amortized, durable, and in working order, they are still profitable to use. Older machine tools tend to be taken out of production in the United States and used for machinery repair and reconditioning, permitting

8. About 15% of annual output of machine tools is exported, mostly to Eastern Europe and to the less developed countries.

newer machines to be used for production. In the USSR the opposite is true; older machine tools are retained in production while many new general purpose machines are used for repair work (as well as production). Hence, the inventory of machine tools in use in the repair sector is actually younger than that in use in production.

36. The Soviet effort to replace its huge stock of general-purpose machines with more modern ones is probably misplaced. Only the machine tools in production need to be modernized. Instead, the USSR needs to reorganize its repair industry in order to increase specialization and cut down on the number of machine tools needed. Moreover, the repair industry ought to become a second-hand market for older machine tools used in production. In summary, the Soviets have sought quantitative solutions to a qualitative problem. The issue is not to replace all machine tools, but the right machine tools.

37. Thus the Soviets are faced with two major problems: a technologically outdated and inadequate machine tool stock; and, an organizational

structure, both of machinery production and repair, that condemns a significant proportion of the machine tool inventory to nonproductive or insufficiently productive use. The strategy adopted to deal with these problems -- replacing older machine tools with newer ones and increasing the use of NC machines -- is only a partial solution, at best. What is needed is a fundamental transformation of the way machinery production is organized in order to maximize the benefits of both NC machines and basic machine tools. Also, machine tool output should be restructured to increase the supply of specialized, especially automated, machine tools; to reduce the output of standard, general-purpose types; and to improve the precision and durability of all machine tools.

Growth of NC Machine Tool Production

38. NC machine tools for the civilian economy have been under development in the USSR since the mid-1950s by a few institutes and plants in the machine tool industry.[9] Until about 1968, research

9. Principally, by the Experimental Scientific Research Institute of Metalcutting Machine Tools (ENIMS), the Leningrad Machine Tool Plant imeni Sverdlov, the Odessa Milling Machine Tool Plant imeni Kirov, the Moscow Ordzhonikidze Machine Plant, and the Gor'kiy Milling Machine Plant.

and development was phlegmatic and slow-paced. Production appeared to lack centralized direction and strong government backing. According to official data, the USSR produced less than 150 NC machine tools in 1967, mostly conventional machines with plugboard control (see Table 3 and Figure 2).

Table 3

USSR and US: Production of Numerical Control Machine Tools

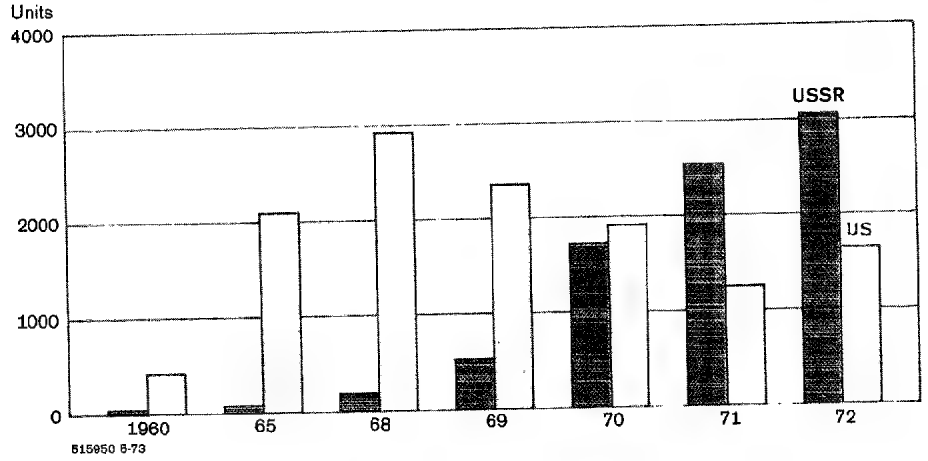
Units

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1975 Plan
USSR Total	**16**	**N.A.**	**N.A.**	**N.A.**	**N.A.**	**49**	**57[1]**	**145[1]**	**197**	**525**	**1,687**	**2,540**	**3,038**	**6,720**
US Total	**402**	**518**	**1,047**	**1,220**	**1,517**	**2,100**	**2,926**	**2,957**	**2,917**	**2,376**	**1,901**	**1,238**	**1,626**	**N.A.[2]**
Point-to-point	368	454	936	1,098	1,345	1,871	2,400	2,336	1,926	1,477	1,116	527	640	N.A.
Of which:														
Plugboard	90	146	157	192	200	267	371	286	174	153	83	51	35	N.A.
Contouring	34	64	111	122	172	229	526	621	991	899	785	711	986	N.A.
Machining centers[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	976	841	651	344	475	N.A.

1 Estimated.
2 Probably less than 4,000.
3 Machining centers include both point-to-point and contouring types

Figure 2

USSR and US: Production of Numerical Control Machine Tools



There is some evidence that planners, for many years, did not fully appreciate the usefulness of NC machines in the production of standardized items.[10]

39. NC machine tools have also been under development in the aviation industry, probably for use in industries producing aerospace and military equipment. Two major aviation institutes in Moscow[11] are known to have had longstanding NC development programs. Regional aviation institutes in Ufa, Kazan', and Smolensk are also believed to be developing NC machines. The types of NC machines being developed in aviation institutes are not known. Furthermore, it is not known whether machines under development by the aviation industry are more or less advanced than those in the machine tool industry.

40. In early 1968 the USSR belatedly recognized the need for NC machine tools and officially announced a major new program to accelerate develop-

10. However, one Soviet study, in the late 1960s showed that about one-third of all machinery output was in batches of 100 units or less, an ideal batch size for the application of NC technology.
11. The Scientific Research Institute of Aviation Technology and the Moscow Aviation Technology Institute.

ment and production. Output was to be increased substantially during 1969-70 and the groundwork laid for greatly increased output during 1971-75. The relatively low state of NC technology and the slow pace of progress in setting up production were given as reasons for the new program. Desire to catch up with US and Western advances in NC technology and pressures from the Soviet aerospace industry also may have been important factors influencing the government's decision to expand output.

41. Responsibility for design and production of electronic control units was vested in the instrument manufacturing industry, and for the development and production of machine tools proper both in the machine tool industry and in the aviation industry.[12] The State Committee for Science and Technology was given some undefined responsibility for the planning of future NC applications.

42. No division of responsibilities between the machine tool industry and the aviation industry

12. The announcement of a major new NC development role for the aviation industry is the first official recognition that this industry has been engaged in development and production of NC machine tools.

was specified, and no agency was designated to carry out interministerial coordination of development and production activities. Hence, it may be assumed that two parallel, and independent, NC development and production programs have been put into force: one to produce NC machine tools for use in the civil machinery sector; the other to provide NC machines for aerospace and military applications.

43. Since the new program was announced in 1968, production of NC machine tools in the USSR has accelerated rapidly. According to official Soviet data, 1,687 NC units were produced in 1970, an increase of more than 200% over 1969 and almost nine times the number produced in 1968. In 1971, output amounted to 2,540 units, an increase of about 50% above that for 1970, and output in the USSR for the first time exceeded that of the United States.[13] A comparison of Soviet and US production of NC machine tools during 1960-72 is shown in Table 3.

13. Soviet output was still below peak US production of 2,957 NC units in 1967. Hence, US NC manufacturing capacity in 1971 was still larger than that of the USSR.

44. A majority of the NC machine tools produced in the USSR are manufactured by the machine tool industry. Data on output of NC machine tools by this industry are available for the years 1965, 1970, and 1975 (plan). In 1965 the machine tool industry produced 42 out of a total of 49 units; in 1970, 1,100 out of 1,687; and in 1975 is scheduled to produce 4,500 units out of 6,720. The residual output originates in plants and institutes of the aviation industry and is intended for use in the production of aerospace and military hardware (see Table 4 and Figure 3). However, it is possible

Table 4

USSR: Estimated Production of Numerical Machine Tools for Civilian and Aerospace/Military Industries

Units

	1965	1970	1971	1972	1973	1974	1975 Plan
Total	**49**	**1,687**	**2,540**	**3,038**	**4,192**	**5,307**	**6,720**
Civil[1]	42	1,100	1,458	1,924	2,560	3,392	4,500
Aerospace/military[2]	7	587	1,082	1,114	1,632	1,915	2,220

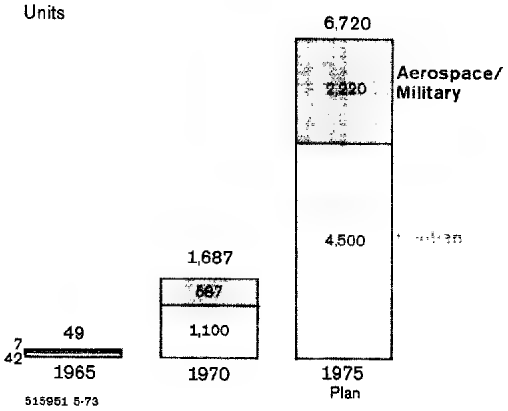
1. Produced by the Ministry of the Machine Tool Industry.
2. Produced by the Ministry of the Aviation Industry.

that some NC machines from the machine tool industry are also used in military production.

45. Data in Table 4 indicate that output of NC machines for aerospace and military production

Figure 3

USSR: Production of Numerical Control Machine Tools for Civilian and Aerospace/Military Industries



amounted to about 15% of total NC production in 1965 and about 35% in 1970. Further, the table shows that the share of NC machine tools for aerospace and military production will stay at about one-third of total production during 1971-75. However, this share may be substantially greater than is implied by the unit output data if measured in terms of the relative commitment of skilled manpower and technical resources because types of NC machines needed for aerospace applications are generally more complex than for civilian uses and have more exacting specifications for precision, versatility, and reliability.

46. Comparison of Soviet and US output on the basis of official Soviet data is difficult and even misleading because of striking differences in the composition of output. Although no official breakdown of unit production by type is available

for the USSR, it is believed, on the basis of data on model types and other information, that most of the NC machines produced to date are point-to-point types, many equipped with plugboard type controls.[14] Some relatively simple contouring machines have been produced, but no machining centers are yet in quantity production.

47. In the United States, highly productive, technically advanced types of NC machine tools dominate the product mix. In 1972 most of the NC machine tools produced were contouring machines (61%). Plugboard NC machines amounted to slightly more than 2% of total NC production. About 29% of output consisted of machining centers.

48. Nearly all Soviet NC systems consist of conventional machine tools that have been modified to accept NC controls, unlike current US practice in which machine tools are designed specifically for use with NC equipment. Such integrated systems generally afford considerably increased precision, reliability, and durability over conventional machines modified for use with NC components.

14. In 1971 the USSR produced 53 different models of NC machines. About four-fifths were point-to-point types; nearly one-half of these utilize plugboard control. Ten models were contouring types.

Modified machine tools perform adequately in applications where the work load is light and high precision is not needed but may be less than adequate under conditions of heavy or multiaxis machining applications. The Soviets may be forced to modify existing machine tools for use with NC equipment in order to save on extensive engineering design lead-times, to avoid complicated industrial problems of changeover to new model production, to stretch a limited design capability, and to achieve more rapid increases in output of NC equipment than might otherwise be possible.

Problems in Soviet NC Machine Tool Development

49. Soviet NC technology lags 7 to 10 years behind that of the United States. Progress has been retarded by backwardness in electronics and data processing technology, shortages of high-quality electronic components and computer hardware, and by the lack of adequately trained engineers, designers, and technicians. In very recent years, shortages of skilled manpower for the development of NC equipment may have been aggravated by com-

petition for computer designers and similar specialists from the Soviet computer industry.[15]

50. The USSR has lagged behind the United States most notably in the development of NC contouring machines and machining centers. A few contouring machines have been built and are in operation in civilian industry but for the most part are limited to 2-axis simultaneous control. According to a very recent source, users of contouring machines in the USSR are using URAL-4 and MINSK-22 computers to generate NC contouring programs. The limited memory capacity of these computers makes it likely that available programming for contouring is limited to relatively simple type programs in 2 axes.[16] The same source indicated that the reliability of existing Soviet NC contouring machine tools is low. One prototype of a 5-axis contouring (milling) machine, reportedly built in 1970, was seen by US

15. Skills needed to develop electronic numerical control units are similar to those needed to develop computers generally. The program to accelerate production of NC machine tools coincides roughly, in time, with a major program to modernize computer production in the USSR.

16. Generally, at least 32,000 (32K) addressable units of memory are needed to write contouring programs in 3 or more axes. The first-generation (vacuum tube) URAL-4 with a 4K memory and the second-generation transistorized MINSK-22 with an 8K memory fall far short of this requirement.

machine tool experts in 1971 at ENIMS, the main scientific development center for machine tools. In the United States, most contouring machines that have been built are capable of machining in 3 axes simultaneously, and many are controllable in 4 or 5 axes.[17]

51. In 1972, six prototype machining centers with magazines holding from 30 to 100 cutting tools were exhibited in the USSR. However, only one of these (a horizontal milling machine) reportedly was capable of contouring in 3 axes simultaneously. The others exployed simultaneous 2-axis point-to-point control. In the United States, most machining centers operate in 3 or more axes with contouring capability.

52. The USSR has not yet developed a standardized computer program for use in generating contouring NC routines. Lacking a standardized program, few plants would be able to use economically multiaxis contouring machines even if they soon became available. Users would be forced to create their own computer programs which, typically, re-

17. These types are used almost exclusively in the production of aerospace and military-related components (particularly jet engine and airframe components).

quires several man-years of development effort. In the United States, several standardized programs have been developed for use with NC equipment and can be applied to most of the common business computers in use. The Soviets have shown intense interest in purchasing in the US one such program, called APT.[18]

53. NC units in the USSR often do not meet the needs of machine tool makers. Complaints in the Soviet press reveal that many NC controllers in production are obsolete and that newer types of controllers intended for machines already in production are not being produced. Frequently, NC controllers are defective and the services of the manufacturers to correct defects are unavailable. In a very recent case, not one of 25 NC controllers ordered by a machine tool manufacturer from the Smolensk plant worked on delivery, and no technical assistance from the manufacturer could be obtained. Moreover, plants of the instrument industry are not meeting planned delivery schedules, and some

18. Automatically Programmed Tool, the most versatile, powerful, and comprehensive NC programming system available. Originally developed at the Massachusetts Institute of Technology, it is now undergoing further development at the Illinois Institute of Technology.

machine tool manufacturers are making their own control units.

54. In addition, Soviet controllers suffer from numerous design and qualitative shortcomings. These include: poor resistance to plant environment (heat, dust, noise, or vibration), improper tailoring to the requirements of the machine tools to which they are mated, shoddy workmanship, and poor quality of component parts, particularly electronic devices, electrical starting and regulating equipment, and tape drive mechanisms. The poor quality of Soviet controllers persists because of lack of customer sanctions against producers and disinterest by the plants of the instrument industry which, very largely, are producing controllers only as a sideline.

55. In the United States, electronic controllers are built with integrated circuits. This greatly reduces size while improving reliability of the electronic portion of NC systems. Soviet controllers generally employ less advanced solid state circuitry based on transistors and semiconductor diodes. In the United States, controllers use mostly 8-track punched tape inputs. In the USSR,

mostly 5-track punched tape is used, although across-the-board conversion to 8-track punched tape is reportedly under way. Eight-track tape is more flexible, particularly for programming multiaxis machining, because it permits more auxiliary machine operations to be encoded.

56. The USSR is attempting to accelerate progress in advanced NC machine tool technology. Intensive research and development activity is under way at ENIMS, at several machine tool plants,[19] and in institutes and plants of the Ministry of the Aviation Industry. In addition to prototypes of advanced multiaxis contouring machines and machining centers that have been built, the Soviets are working to develop even more advanced systems such as adaptive control and DNC.[20] One adaptive control system reportedly has been built in prototype.

57. The Soviets have demonstrated good progress in DNC, at least in the laboratory. At the Moscow "Stanki-72" machine tool show in March 1972, the USSR exhibited a prototype DNC system called a "link line" that integrated a mixture of NC machine tools, including contouring machines and machining

19. Notably, Gor'kiy, Ivanovsk, Leningrad (Sverdlov), and Odessa.
20. See paragraph 11.

centers, into a totally self-contained machining complex. Automatic parts handling devices transfer the workpiece through sequential machining operations, and a central computer controls the entire machining process. The USSR may intend to use link lines for the production of spare parts in an expanding network of regional repair centers in the machinery sector.[21] One such DNC system is in use in the United States, and others are slated to be produced.

Western Technical Assistance -- Key to Five-Year Program

58. Since 1968 the USSR has gained access to Western NC technology through technical exchange and cooperation agreements with Western countries and Japan. Since the United Kingdom first agreed to exchange "technical information" with the USSR in NC technology in 1968, the scale and scope of contractual arrangements have steadily widened. In 1970, Alcatel of France contracted to manufacture

21. Centralized repair and spare parts production for metalworking machinery is being organized in the USSR under the All-Union Association for Machine Tool Repair (Soyuzstankoremont) which is subordinate to the Ministry of the Machine Tool Industry. The Association currently operates nine specialized repair and spare parts facilities and plans to add five more during the 9th Five-Year Plan. As yet, they account for only a small fraction of repair work.

electronic controllers for the USSR. At least some of these are to be mated with machine tools produced by the Leningrad Sverdlov plant and marketed in France and elsewhere in Western Europe. The Ryazan machine tool plant also, reportedly, is manufacturing NC machine tools using Alcatel controls, probably for the domestic Soviet market. In 1971, Saab-Scania of Sweden and Siemens of West Germany entered into similar arrangements for supplying the USSR with electronic controllers to be mated with Soviet machine tools and marketed in Sweden and West Germany, respectively.

59. In 1972, Japan added a new dimension to foreign technical assistance to the USSR in the field of NC technology. Fujitsu Ltd. contracted to supply the USSR with production know-how for its FANUC series of electronic controllers [22] and associated hardware (pulse motors). Similarly, discussions are under way with Olivetti of Italy for the purchase of manufacturing know-how for Olivetti controllers.

22. Three different models; the most advanced model is capable of 3-axis contouring with two simultaneously controlled axes.

60. The extent of Western sales of complete NC systems to the USSR is not known. Reportedly, NC machines have been purchased from Sweden, Switzerland, the United Kingdom, West Germany, and Japan. One US executive alleges that Sweden sold 25 complete NC contouring systems to the USSR in 1971.

61. The USSR is actively testing and evaluating Swedish and Japanese NC machines and their controllers at ENIMS. It has been reported that Fjuitsu may supply ENIMS with an advanced DNC system. In addition, the USSR is keenly interested in advanced US NC machine tools, especially multiaxis machining centers. Recently, the USSR has negotiated with a large US machine tool producer to purchase three advanced multiaxis machining centers valued at nearly $2 million to be installed at ENIMS.

62. The intensive Soviet effort to purchase advanced NC machines for ENIMS may indicate that foreign systems are undergoing competitive evaluation as a prelude to future Soviet purchases. Almost certainly, it means also that foreign NC design technology is being extracted by the Soviets. This approach could save the USSR many costly man-years of engineering development effort.

63. The USSR is also taking advantage of gains made by East Germany in NC technology. East Germany has the most advanced NC capability in Eastern Europe and is serially producing NC machine tools, although most are believed to be point-to-point types. In addition, some machining centers also are being produced, and a DNC system has been developed. East Germany sold 80 NC machine tools to the Soviets in 1971 and planned to deliver 200 in 1972. East Germany has opened a machine tool center at the Krasny Proletariat Machine Tool Plant in Moscow to familiarize the Soviets with the operation of East German NC machine tools and to train Soviet technicians in NC programming and maintenance.

Plans and Prospects

64. By 1971 the USSR already had become the world's largest producer of NC machine tools. By 1975, if planned goals are realized, the USSR also may have the world's largest capacity to produce NC machines, by number if not by value. The USSR plans to increase output at an average annual rate of about 32% a year -- 300% for the five years -- implying an output of 6,720 machines in 1975. Prob-

ably US output in that year will not exceed 4,000 units. Output in the USSR increased by 80% during 1971-72 and is planned to jump an additional 38% during 1973. An average annual rate of about 30% during 1973-75 is needed to fulfill planned output goals.

65. Despite the high growth rate implied for 1973-75, the USSR probably will meet its 1975 unit output goals for NC machine tools. High growth rates are possible because of the Soviet practice of mating NC control units to conventional models of machine tools that are already serially produced. Furthermore, acquisition of Western-made NC controllers through present arrangements with firms in Western Europe and Japan will facilitate growth in unit output.

66. Technical improvement in the quality and design of NC controllers is planned, including conversion from transistorized circuitry to integrated circuits and a shiftover to 8-track punched tape for most models beginning in 1973. The resolution of controllers and the machining accuracy of NC machine tools also are to be raised. The Tomsk Mathematical Machine Plant is to become a special-

ized producer of controllers -- the largest in the USSR. Nevertheless, Soviet machines are likely to remain qualitatively inferior to US and Western counterparts. Most Soviet-made controllers probably will not incorporate modern design based on integrated circuits, although Soviet NC machine tools that use Western-made controllers will be based on integrated circuit designs.

67. Product mix is to be expanded during 1971-75 to include more than 100 models, including several different models of machining centers. Eleven models of NC machines are to be serially produced under conditions of "flow line mass production." However, the technological composition of Soviet output is unlikely to match that of the United States or Western Europe. Most models in production will be point-to-point or simple contouring types. About 2,500 NC machines, more than 35% of 1975 planned output, will be NC lathes, probably highly standardized types that are easiest to produce. Multiaxis (three or more axes) contouring NC machine tools and machining centers probably will continue to exist mostly as prototypes.

68. Cumulative output of NC machine tools during 1971-75 should total nearly 22,000 units, about 2% of the planned output of conventional metalcutting machine tools. The economic effect of these machines will depend on how they are used and in which applications. As with computers, their potential may far outweigh actual performance in the Soviet environment. In aerospace and civilian production involving runs of 100 units more or less, NC machines can be helpful. If, as is currently the case with many conventional machine tools (and computers), they are used only part time, as in repair, their potential will be wasted. The effect of NC machines ought to be more significant in the post-1975 period, as the quality and capabilities of Soviet NC machines improve.